amiable efforts less likely to be crowned by success. In support of this view, we would call attention to the generous letter of thanks from the foreign delegates which appeared in last Saturday's *Times*.

The first sitting for the reading of papers was held in the Imperial Institute on Tuesday, the 6th inst. The Prince of Wales, as President of the congress, delivered an opening address, and was followed by the First Lord of the Admiralty, and by Lord Hopetoun, the President of the Institution of Naval Architects. The congress was then divided into two parts, that relating to Naval Architecture being held in the Main Hall, whilst the Marine Engineers took possession of the East Conference Hall. The first paper taken in the former section was a contribution by M. Émile Bertin. It was on "hardened plates and broken projectiles," and discussed the effect of "Harveyising" steel armour. This paper was to some extent based on one read previously by Mr. C. Ellis, of Sheffield. The author supposed that a cap placed on the point of a projectile would assist in penetrating the plate. This system was first tried in England and met with approval, and judging by M. Bertin's paper he supports the device. The practical success of the Harvey system of treatment—which is in the nature of case-hardening—is now so fully established that it is needless to follow up the subject in this brief sketch; but, to those who wish to pursue the matter in its more scientific and abstract features, the paper in question will afford both instructive and interesting reading. It must, however, be taken with the illustrations.

"Non-flammable wood" was the subject of the next paper, contributed by Mr. C. Ellis, of Sheffield. In the process dedescribed, timber is placed in a cylinder and a vacuum is formed. Steam is then admitted, and the moisture is drawn off with it. A vacuum is then again formed, and a fine spray of a liquid containing certain salts is injected into the cylinder, the fibre being thus thoroughly impregnated by the chemicals. Under these circumstances the wood will not support flame. So far there does not appear to be anything very novel in the principles of the process, though there may be in the details, and possibly the "certain salts" cover an important point upon which information was not given in the paper. The advantage of wood used in warships being "non-flammable" is beyond question.

In the Marine Engineering Section, at which Sir Edward Reed presided, Sir John Durston and Mr. J. T. Milton contributed the first paper, which comprised "a review of the history of the progress of marine engineering in the Royal Navy and Mercantile Marine from the foundation of the Institution of Naval Architects to the present day." This was one of those elaborate contributions to the literature of the subject which will be invaluable to the historian of the future and the writers of books in general, but which it would be foolish to attempt to abstract here. Its title is sufficient to denote its scope, and the high reputation of the authors is sufficient to stamp the paper as a standard work. A paper by M. Sigaudy was next read. It treated upon water-tube boilers in high-speed ocean steamers, and gave details of actual practice in small vessels, and proposals for larger ones, strongly supporting the suggestion that small tubes, or, as they are called in England, "express" boilers, should be used on ocean-going vessels.

On the second day of the congress, Wednesday, July 7, the Naval Architecture Section was opened by the reading of a paper by Sir Edward Reed, on the mathematical theory of naval architecture. This was another monumental paper worthy of the subject and the year. It led to a discussion largely of a nature complimentary to the author, who had managed to compress a large mass of information of a general nature within the limits of his memoir, and to do this without making the subject repulsive by its dryness to the average reader of such contributions. Captain Tuxen, Chief of the Construction Department of the Royal Danish Navy, next read a paper, in which he described some of those admirable railway ferry steamers which break their way so remarkably through the ice-bound waters of his native land. The last paper read in this Section was contributed by Mr. J. Johnson, of Göthenburg, and dealt with "graphic aid in approximating hull weights."

In the Marine Engineering Section, in which Sir Nathaniel Barnaby occupied the chair, the proceedings were opened by Mr. G. W. Manuel reading a paper on "crank and other shafts." Mr. Manuel, as is well known, is the Chief of the Engineering Department of the P. and O. line, and his success in regard to the absence of accidents to the shafting of vessels under his charge has been remarkable. In this respect, however, he has been fortunate in being able to give such substantial proportions to this feature in machine design that success is not altogether to be attributed to good fortune; indeed, it has been said that if Mr. Manuel were to make his shafts of cast iron they would be reasonably safe. By aid of diagrams many instructive illustrations were given of the manner in which shafts fail, often by fatigue. Mr. Manuel is not an advocate of hollow shafts, and though he gathers countenance for his views to some extent from the fact that hollow shafts are not general in the mercantile marine, we do not think the reasons he puts forward would meet with the support of many naval engineers. The paper was, however, full of information, and was followed by an interesting discussion.

Mr. Sydney S. Barnaby followed with an excellent paper, in which he gave a lucid explanation of the theory of cavitation with screw propellers, that new disease which is the outcome of modern high speeds, and to which marine engineers are now turning their attention. We commend Mr. Barnaby's paper to all naval architects who have not mastered this somewhat intricate subject. The last paper read was contributed by Dr. H. S. Hele-Shaw, Professor of Engineering at Victoria University, Liverpool. Its title was "Experiments on the nature of surface resistance in pipes and on ships." This was a most interesting contribution, and might with advantage have occupied more time than could be allotted to it. Doubtless, however, the experiments shown will be brought forward again in other guise. The author's method of studying resistance is to inject water between plates of glass, placing such obstructions to the flow as may be desired, and to throw the image on the screen by the lantern. In order to get a visible result of the streams and eddies, air is injected into the water, or sometimes a coloured liquid. The result is most satisfactory, and cannot but lead to considerable light being thrown on this interesting and very debatable subject. It would be impossible to follow the author in the details of his paper without the aid of graphic representations; but the effects produced on the screen were mostly illustrated by engravings taken from photographs, and presented with the paper. It is to be hoped Dr. Hele-Shaw will carry his work further, and, by their aid, give substantial guidance in this field of research.

The foreign delegates and some of the home members of the Institution continued the work of the congress by visiting Glasgow and Newcastle, where a few of the most prominent shipyards—Fairfield, Denny's, and Elswick—were visited.

LIGHTHOUSE PROGRESS, 1887-1897.

IN 1887 some account was given in NATURE of lighthouse work and progress in the United Kingdom during the preceding fifty years. I propose in this article to consider briefly the same subject in connection with the past ten years, so that the whole may form a summary record of what has been attained during the Victorian era in this important branch of optical and mechanical science.

And, first, it may be asserted that the period of the Queen's reign, distinguished as it is for so many developments of new industries, can boast of none more valuable or more interesting than this now in question. Fresnel's monumental invention in 1819 of the dioptric system of lights was at once welcomed and realised by the French Government, who have since always encouraged and supported the native constructors of lenticular apparatus. But it was only after thirty years from this date that the lighthouse industry was planted in England, if we except the experimental attempts of Messrs. Cookson, of Newcastle. The systematic and permanent establishment is due to the public spirit and the enterprise of Messrs. Chance Brothers, subsequently aided by the mathematical talents and personal direction of Mr. James T. Chance, whose services to the Royal Commission on Lights of 1860, as well as to the Trinity House, and whose writings on lighthouse optics are widely known. It is said that great pecuniary loss resulted from the first efforts of Messrs. Chance, but they have gone on steadily and alone to the present day, with little or none of official aid or encouragement, and they are certainly entitled to full credit for having done so much and so well for the coast illumination of their own country and the world.

I adopt the main divisions of the former articles, viz. Towers, Apparatus, Lamps.

There is not much to be noted in regard to the architecture or engineering features of the iron and stone lighthouses erected in Britain during the past ten years. The principal island towers are in the Shetlands, viz. Stroma, Fair Island, and Sule Skerry, which is one of the dangerous reefs known as *skerries* so thickly strewn on the northern and western coasts. These all are the successful works of Messrs. D. and C. Stevenson. The Trinity House has not erected any rock or pile tower since the Round Island in 1887.

Of lightships there have been established two only, which are at the mouth of the Thames to mark the Edinburgh Channel, and, like all the Trinity lightships, they have 21-inch silver-plated reflectors, with the powerful two-wick oil burners of Sir J. Douglass, the flash from one face of the light being equal to 20,000 candles.

To nearly all the light-vessels in our waters sound-signals, chiefly of the siren type, have been added, which are invaluable in the frequent sea fogs that beset our shores, since by a marvellous beneficence of nature—for the proof of it we are chiefly indebted to the researches of Tyndall—fog that quenches light deepens the intensity of sound. The siren is now an indispensable adjunct to our principal land-lights, and a visit to the Isle of May, the St. Catherine's, or Ailsa Craig, would well repay any one desirous of seeing the latest and best arrangements for the production and transmission of its weird and inimitable notes.

Many of our land lights and floating lights have been connected with the main telegraphic system "for life-saving purposes only." There were, at the end of 1896, 27 such stations in England and Wales, 14 in Scotland, and 11 in Ireland. The most suitable places were selected for the observation of passing vessels and for the immediate transmission of reports of casualities to the nearest points available for help. It is by no means an easy work to make a durable telegraphic connection with a lightship, and with all stations the cost is considerable; but the benefit is so marked that this communication, long and urgently demanded, will soon be extended to all other sites on the coast where the advantage is evident, and the difficulty not insurmountable.

Of the new sea lights in the decade under review may be mentioned the Girdleness, the Rattray Head, the Tarbetness, the Stroma, the Scaddon, the Skroo, and the Sule Skerry, all on the Scottish coast; and the Round Island, the St. Catherine's electric, the Spurn Point, and the Withernsea, on the English coast. The characteristics of several older lights of fixed sections have been changed, such as the Whitby, Coquet, Orfordness, Southwold, and Needles, which have been made occulting lights.

To complete the bare statistics of the subject, it may be mentioned that the whole number of lights of all sorts and sizes on the coasts of the United Kingdom on December 31, 1896, according to the Admiralty List, was 1095, an increase of about 200 over the number of ten years ago. Of the 1095 lights, not more than 11 or 12 per cent. may be classed as of sea-power, and 6 or 7 per cent. as lightships. The rest are port, harbour and pier lights, showing a very abundant supply of local signals apart from the great coast signals controlled by the three Lighthouse Boards.

It would seem, indeed, that the programme of coast lighting is almost completed—at least as regards England. A powerful oil light is to be erected by the Trinity House in St. Mary's Isle, on the north-east coast, and two others in Lundy Isle in the Bristol Channel, where also, at Lynmouth, an electric light is proposed. A further improvement in the fine reflector light of Beachy Head is also spoken of. The Northern Commissioners will erect a first-class light at Noup Head, in the Orkneys, and another on the Flannan Islands in the Hebrides. For Ireland no new light appears to be intended for the present; but the improvement of the Fastnet, the most outlying of our lights westward, must soon be taken in hand.

The *lantern* which crowns the tower and protects the apparatus of a land or rock lighthouse has been materially improved in its construction. The perfect lantern is of adequate area to contain the light and accessory parts, and afford convenient space for service. Its diameter for a sea light is rather 14 feet than 12 feet. It is of circular form throughout, having a cast-iron pedestal of sufficient height to carry an inside and an outside gallery for cleaning purposes. The framing is of gun-metal or wrought iron. The half-inch plate-glass of the purest quality, while resisting wind and weather to a great extent, intercepts the least possible light from the lenses. There is provided abundant ventilation to sustain the central lamp, and refresh the keepers. The best contribution of the Trinity House to the structure has been the large cylindric ventilator on the double copper dome, by which the last-named advantage is mainly secured.

Turning to the optical features of the decade, let us see what changes have affected the two main factors of illumination—the fixed light and the revolving light. The ever-increasing number of ships and ports, and the sustained demand for greater and greater speed of vessels, and for sea signals that shall serve more and more to meet all conditions of weather and to discriminate harbours and channels of approach, have stimulated the efforts of lighthouse engineers in the two directions of power and distinctiveness.

The *characteristics* introduced of late years have been confined for the most part to new combinations and periods of group flashes, or of single equal flashes. Mixed lights of fixed and revolving sections, and therefore with unequal degrees of visibility, are no longer in good repute, although, in the French service especially, they are still retained. Colour also is being gradually abandoned for sea lights. For harbour lights, however, it is still freely resorted to, most of all in Northern Europe, as in the Omo light, Baltic Sea, where in one small apparatus there are no fewer than six characteristics with seventeen variations.

Power has been sought—

(1) By the substitution, wherever practicable, of annular for cylindric lenses, or of revolving for fixed sections.

(2) By the longer focal distance and larger condensing surface of these lenses, and by superposing them in vertical series.

(3) By using an illuminant of maximum intensity, whether oil, gas, or electricity.

(4) By certain variations and extensions of the Fresnel refractors, giving a higher coefficient of beam.

(5) By invoking the principle of the full perception of the light from an annular lens moving in rapid rotation with very short intervals between the flashes. This is known as the *feu éclair*.

(6) By rotating an opaque screen around a lamp, or by raising and lowering quickly an opaque cylinder, or by cutting off and relighting of gas in rapid alternation.

Let us consider these in order.

(1) The reasons for the disuse of fixed sea lights, except in the case of marking or intensifying particular sectors, are chiefly their want of power to penetrate to their natural horizon, and the increasing number of bright fixed lights on ships and on shore, which may in certain conditions lead a navigator into danger from the difficulty of distinguishing them from a lighthouse. The flashing light, with its superior power and numerous possible distinctions, is the best safeguard against this.

(2) The hyper-radial lens of 1330 millimetres focal distance, first suggested (as Prof. Tyndall declared) by Mr. John Wigham, and concurrently at least by Mr. Thomas Stevenson, who less fitly termed it hyper-*radiant* (a good name for the ten-wick oil flame, or ten-ring gas flame), has quite justified the expectation of lighthouse engineers as a convenient and powerful instrument admirably adapted to the large burners now employed. This lens, like its predecessor of 920 millimetres radius, is commonly used without catadioptric prisms, as in the Spurn Point light. The disuse of prisms effects a great saving in cost at but an inconsiderable diminution of power where a high vertical angle of refraction is adopted. Yet it must be admitted that this is at the expense of symmetry and elegance. The French light on Cape d'Antifer is a fine example of the hyper-radial system, embracing a full complement of prisms.

There has also been constructed, at Mr. Wigham's suggestion, as an experiment, what he aptly calls a giant lens of 2000 millimetres radius, but it is not yet adopted in practice.

The superposition of lens lights, each with its own burner, is an obvious means of gaining power, and it is remarkable that, although first suggested in 1859, it was not practically utilised with dioptric apparatus until 1872. Whether biform, triform, or quadriform arrangements be resorted to, the advantage of concentrating or reducing the intensity of the beam according to atmospheric variations is inestimable, and the adaptation reflects undoubted credit on Mr. John Wigham, whose polyannular gas-burner on a like plan had been already approved. The triform

Tory Island light, fitted with these burners, and variable in power from 17,500 to 326,500 candles, may be cited in illustration.

(3) The maximum intensity of an illuminant must still be sought in the electric arc. Gas and oil remain substantially equal compared in lamps of the same size and sort, the superior applicability of each being determined by local conditions. In Ireland the Wigham expanding burners give a marked prominence to the gas, which is copiously used in them. In England and Scotland mineral oil is preferred, its quality being carefully maintained at the highest standard. The old disability of this illuminant, the risk of explosion, has been almost nullified by the production of a petroleum whose flashing point is 230°, and long experience has confirmed its great value. On the other hand, the gas called "incandescent" has been introduced, the best form of it being of the Auer-Welsbach type. The brilliancy of this gas is perhaps only second to that of the electric arc, but the perishable character of its accessories exacts great caution in using it, and it has not as yet been employed in any sea light in this country, although it is already so adopted in France. A mixture of oxygen and coal gas, and one of oxygen and oil vapour, which have been tried in street lamps and otherwise, have been recommended for lighthouses, but not hitherto accepted.

Electricity has been, as it were, on its trial since the South Foreland experiments of 1885, and the evidence affecting it is hardly yet complete enough to justify a final verdict. The result established at the South Foreland was that the electric light is the most powerful under all conditions of weather, and has the greatest penetrative intensity in fog. The Committee of the Royal Society, which examined in 1890 this report of the Trinity House, found that the experiments did really justify the results given.

The twelve years that have elapsed since the trials at the South Foreland have on the whole tended to qualify the conclusion as to the penetrative power in fog. Three lights—two of the group-flashing, and one of the single-flashing character—constructed by Messrs. Chance, may be cited on this point. The triple flash of the Tino light (near Spezia) has been unmistakably discerned in rain and fog at a distance of more than twenty miles. On the other hand, the Isle of May light has been invisible in a thick atmosphere not amounting to fog, at a distance of twelve miles, and in a dense fog at half a mile; and the St. Catherine's light was equally invisible to the *Eider* before she grounded on the Atherfield ledges. It has been, indeed, asserted that the St. Catherine's has often been unseen at a quarter of a mile distance.

The truth appears to be that the electric light is very sensitive to atmospheric conditions, which are so many and so various, and that in thick weather it parts with its power in a much greater ratio than does a gas light, or even an oil light. There is a degree of fog which quenches the sun, while the large luminous surfaces of the superposed gas lenses project on the fog a reddish colouration, and the fog itself thus becomes a signal to the mariner when, as it were, in the words of Persius, "Pinguem nebulam vomuere lucernae." It would be most dangerous, however, for the mariner in a fog to approach the coast presuming on this quality of a light in whose vicinity he supposed himself to be. The lead, the anchor, the horn should be his trust till the veil lifts, and the electric beam shines out in full splendour.

There has occurred no important change in the *burners* of sea lights. The Trinity House improved six-wick, or rather five-wick, remains, if not the largest, the best working oil burner, with a power of 800 candles. This is used generally for lights of the first and second order, while the four-wick, with a power of 360, is used for third order lights, and the eight-wick, of 1200 candles, for hyper-radial lights. The lamp is of the "pump" or the "pressure" type, and contains from 10 to 100 gallons of oil. It is probable that, owing to considerations of space and economy, the gravity system may again be resorted to with enlarged reservoirs seated on the lantern-roof. The electric arc is used with carbons of from 15 mm. to 65 mm. diameter, and currents of from 50 to 400 amperes. The incandescent filament is not found equally appropriate. The luminous intensities obtained from the arc range from five to fifty thousand candles. Both direct and alternating machines are employed. The installations at St. Catherine's and the Isle of May are of the most complete character, and do honour to the distinguished engineers of the Trinity House and the Northern Commissioners.

It may be mentioned that for positions difficult of access, lamps having special wicks and reservoirs for oil or gas, capable of burning from ten to thirty days, are now in use, though, of course, these are only available for small isolated lights.

(4) The improvements since 1887 in dioptric lights are few, and, with one exception, are of no striking importance. The great invention of Fresnel, perfected by the beautiful holophotal arrangements of Stevenson, has remained the cardinal principle of all modern lights of the lenticular type. But the inevitable tendency to modify and improve has resulted in several proposals of more or less merit. Mr. Alan Brebner had, in 1882, submitted an ingenious plan for producing vertical and azimuthal condensation by single agency in cases where straight prisms placed outside the main apparatus had been employed to intensify one or more sea sectors. This method, however, has been seldom, if at all, adopted. Again, Mr. Brebner, in 1884, had recommended a plan of dipping a portion of the beam to some intermediate distance between the lighthouse and the horizon to meet the case of a fog which the strongest beam can only very partially penetrate. This, or some analogous plan, has been tried, but has not prevailed. The advantage of withholding from the horizon a substantial part of the beam, and deflecting it anywhere, is extremely doubtful. The depth and direction of a fog are always uncertain elements. The lighthouse may be surrounded by it while the offing is clear, or *vice versâ*. And it would be in equal measure mischievous to encourage the mariner to stand in, looking for a signal which he might never see, or see too late; and to entrust the lightkeeper with the power to deflect the light according to his own judgment. In 1892, Mr. Charles A. Stevenson published in NATURE an account of his spherical and equiangular refractors which remedy a certain loss of emergent light in the Fresnel refractors. In 1894, Mr. Stevenson further developed his design, claiming for it, within practicable limits, an advantage of at least 10 per cent. in increase of light as compared with the Fresnel lens. The improved refractors have been adopted with success in several of the Scottish lighthouses. In 1895 and 1896, Mr. John A. Purves contributed an able mathematical analysis of equiangular prisms and a new form of spherical central lens, called the Inverse Refractor (the facets of the lens turned inwards), to be used in connection with Mr. C. Stevenson's equiangular prisms. Messrs. Chance have raised the Fresnel lens from 57° vertical to 80°, using glass of the same refractive index, and this angle has been adopted by the Trinity House with great advantage.

(5) The one exception referred to in regard to the minor improvements of optical apparatus since 1887 is the "lightning light," an adaptation of serious importance which has attracted the attention of lighthouse engineers in nearly all maritime countries. The shortening of the interval between the flashes of a revolving light, so that the mariner, especially when in a fast liner, may have more speedy cognisance of the signal that guides him, has become a plain necessity, and led to the gradual reduction of the period from 60, 45 and 30 seconds to 20, 15, 10, and even 5 seconds, reducing proportionately the duration of the flash. So far the principle of the *feu éclair* has been approached. But much more than this is demanded. No one has advocated more strenuously than Lord Kelvin, himself a sailor and a benefactor of sailors, the acceleration of revolving lights. No one has laid it down more clearly that one-ninth or one-tenth of a second is sufficient for the eye to receive the full lustre of a lens passing it. Any longer duration is a loss of time, and therefore of intensity. German and French physiologists have confirmed this, and it is the principle on which the *feu éclair* system is based. In its application, then, if for any "order" of light the maximum of power be desired, the largest available lens in vertical and horizontal angle, combined with a totally reflecting mirror and a central flame of adequate dimensions, must be adopted. If two or more lenses be used, singly or grouped, the intensity of each flash is proportionately less, the interval of time, say five seconds, between the single flashes or the groups of flashes, being the same as where there is only one lens. In this manner the greatest intensity and the shortest interval are secured, and the characteristic as presented to the mariner seems theoretically perfect. The first general introduction of the "lightning light" is due to M. Bourdelles, the chief of the French Lighthouse Administration, under whose auspices several lighthouses on the coasts of France have already been endowed with it. In England Messrs. Chance have constructed, in 1895, for Cape Leeuwin, Western Australia, a "bivalve" apparatus of the first order, with an experimental duration of beam of one-fifth of a second,

and they have placed, this year, in the Exhibition of the Imperial Institute a "univalve," or one-lens apparatus, of the third order. Both these lights are on the *feu éclair* system.

Successful as this system appears to be, it should for the present be regarded as on its trial, and as awaiting the collective judgment of mariners on certain points. And meanwhile it should be estimated as supplementing, not displacing, the well-tried forms of apparatus at the disposal of the lighthouse engineer.

A notable adjunct to the new rapidly rotating lights is the mercury-float carriage, by which the effect of weight and friction is largely diminished. Another excellent quality of this arrangement is its suitableness for stations where earthquakes prevail, as it provides an elastic connection between the optical apparatus and the pedestal, instead of the rigid bearings in the older forms of carriage. If the Curaumilla lighthouse in Chili had been fitted with the mercury-float, it is probable that it would not have been wholly ruined by the shock.

(6) The principle of *occultation*—that is, of interrupting the fixed beam of a cylindrical lens of an oil light by a dark shade moving round or over the flame, or in a gas light by cutting off the gas—is acknowledged to be of extreme usefulness, and has been applied to many of the fixed lights of our coasts. It is not that any power is really added to the light, but that the quick alternation of light and dark in various groups or periods imparts a quasi-intensity to the beam, and a valuable set of characteristics for the mariner. The law of contrast has a physiological effect here, as it has in another manner with the *feux éclairs.* It is an extreme example, but it rests on trustworthy evidence, that the occulting light of Ventotene Island, near Naples, which is of the sixth order only, has been seen from a distance of nineteen miles, its normal range being nine miles. Using the words of Cicero with another application, it may be truly said, "Eo magis elucet quo magis occultatur."

Investigations into the amount of light reflected and transmitted by certain kinds of glass—lighthouse glass among the rest—have been most ably conducted by Sir John Conroy, Bart., at Oxford, in 1888. He traversed by newer methods and with surer results the ground of many observers, from Augustin Fresnel to Lord Rayleigh; and he demonstrated that "the values of the transmission-coefficients for light of mean refrangibility show that for 1 centimetre the loss by obstruction amounts to 2·62 per cent. with crown glass, and 1·15 with flint glass." The refractive index of lighthouse glass lying between 1·52 and 1·54, the loss may thus be practically taken as 2½ per cent. for 10 millimetres of thickness.

The intensities of lighthouse apparatus have of late been diligently considered by lighthouse authorities with the view of determining, once for all, the relative values of the six orders of lights, and of the lamps appropriate to them, and also of publishing the results in the Admiralty Light-list. A large amount of uncertainty and misconception seems to have prevailed on this question. M. Allard, in 1876, in a celebrated memoir, gave an elaborate exposition of the whole subject, but his conclusions, always tending to excess, have not been accepted by more recent investigators.

Other estimates, official as well as private, and more or less discordant, have from time to time appeared, both in this country and France. The factors of evaluation, such as radius, lens-surface, vertical section, flame, reduction for losses, &c., have been combined in different ways by different persons, and some of their conclusions must be regarded as merely empirical. But in 1891 and 1892 a serious attempt was made by a committee of the chief engineers of the three Lighthouse Boards to compile an accurate schedule of intensities with photometry as a basis. Taken as a whole, the values arrived at are fairly acceptable, not certainly erring on the side of excess.

But as yet only the lights with oil or gas for illuminants have been determined.

Electricity appears even more difficult to deal with, and no intensities have been assigned officially to any of the electric lights in the British Islands.

Thus it is uncertain whether, for instance, we are to consider the Isle of May as of six millions of candles, or of twenty-six millions, both estimates resting on competent professional authority. The lights on the *feu éclair* system, oil and electric, are obviously less amenable still to formulæ which may give their coefficients of intensity, although French writers do not hesitate to define these, and deduce thirty or forty millions of candles as "ayant la consécration de la pratique."

It is much to be desired that as a sort of sequel to the publication of the intensities of lights—at all events, of the British lights—there should be provided a form for every vessel under the control of the Board of Trade, in which a return should be made of the appearance of every light approached or passed, with statement of the weather, distance, name and character of the light, &c. These returns, duly kept and handed to the Board of Trade on the first opportunity, would gradually constitute an invaluable record of the merits or demerits of our lights, instructive to the engineer, and, through him, beneficial to the mariner. I have repeatedly, but in vain, urged this expedient on the authorities.

The administration of lighthouses in this country has undergone no change in the past decade, nor, indeed, since 1861, when the Royal Commission on Lights recommended that a Central Board should be constituted instead of the quadriform government then, as now, in force, and gave excellent reasons for the recommendation. The further experience of thirty-six years has amply confirmed the earlier conclusions on this subject, and has brought into stronger relief the example of the French Administration. Some slight approach to the desired reconstruction may be indicated in the Report of the Committee of Inquiry on the Mercantile Marine Fund of 1896, paragraph 71, in the following words: "From the evidence brought before us we unanimously recommend the formation of a small committee containing representatives, possessing as far as possible nautical knowledge, of the Trinity House, the Scotch Board and the Irish Board, which should be summoned at least once a year to advise the Board of Trade upon the desirability of all new works, whether in respect of lighthouses, steamers, buoys or signals, together with all renewals, alterations and important repairs."

But however we may regard the system of government of our lighthouses in contrast with the French system, and desire its amelioration, it is impossible to deny that the United Kingdom has during the Victorian era produced men who individually have done fully as much in every part, theoretical and practical, of lighthouse science as have the distinguished men of the sister country. In one group we can point to the names of Faraday, Airy, Thomson and Chance. In another to those of Stevenson, Douglass, Hopkinson and Matthews. In yet another to those of Farrar, Nisbet, Sydney Webb, Trevor, Wharton and Nares.

These men have enriched and illustrated lighthouse mathematics, engineering, optics, mechanics and nautical and general administration, in a manner and with a success to be gratefully remembered in our day, and never to be forgotten in the new developments of the years to come. J. KENWARD.

[*Note.*—I would invite the attention of visitors to the Imperial Institute to the very ingenious and effective illustration of the progress of British coast lights during the past sixty years, by means of two large illuminated maps and a relief plan. This is exhibited by the Trinity House, whose collection of models, lenses, reflectors and burners is also very commendable.—J. K.]

THE LIMITS OF AUDITION.[1]

IN order to be audible, sounds must be restricted to a certain range of pitch. Thus a sound from a hydrogen flame vibrating in a large resonator was inaudible, as being too low in pitch. On the other side, a bird-call, giving about 20,000 vibrations per second, was inaudible, although a sensitive flame readily gave evidence of the vibrations and permitted the wave-length to be measured. Near the limit of hearing the ear is very rapidly fatigued; a sound in the first instance loud enough to be disagreeable, disappearing after a few seconds. A momentary intermission, due, for example, to a rapid passage of the hand past the ear, again allows the sound to be heard.

The magnitude of vibration necessary for audition at a favourable pitch is an important subject for investigation. The earliest estimate is that of Boltzmann. An easy road to a superior limit is to find the amount of energy required to blow a whistle and the distance to which the sound can be heard (*e.g.* one-half a mile). Experiments upon this plan gave for the amplitude 8×10^{-8} cm., a distance which would need to be multiplied 100 times in order to make it visible in any possible microscope. Better results may be obtained by using a

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[1] Abstract of a lecture delivered at the Royal Institution on April 9, by the Right Hon. Lord Rayleigh, F.R.S